

Male and Female External Genital Structure of *Aenetus virescens* (DOUBLEDAY) and Its Male Genital Musculature (Lepidoptera, Hepialidae)

Kyoichiro UEDA

Kitakyushu Museum of Natural History Yahata Station Bldg., 6-1,
Nishihonmachi 3-chome, Yahatahigashiku Kitakyushu, 805 Japan

Abstract The male and female external genital structure of *Aenetus virescens* (DOUBLEDAY) are described and figured. The musculature of male external genitalia is also analyzed. On the male external genitalia, the following character-states are characteristic; 1) the absence of mesosome, 2) valva with an acutely pointed long process at the middle portion of its ventral margin. On the musculature of male external genitalia, the m.5 (vinculum-valva) is very broad and well developed. Some types of mesosome in the male genital structure of Hepialidae are shortly discussed.

Although some problems have been remained unsolved on the homology of mesosome, this structure is well developed in the male genital structure of a number of groups of Hepialidae and it is one of unique characteristics of the family. It has been reported that the mesosome plays an important role to couple male with female, and functions as "ventral uncus" (BIRKET-SMITH, 1974; UEDA, 1981). Among some groups of Hepialidae, which are distributed in Southern Hemisphere, however, it is often observed that this structure is not well developed or entirely absent (COMMON, 1966; DUMBLETON, 1966; ROBINSON, 1977). *Aenetus virescens* (DOUBLEDAY) endemic in the North Island of New Zealand belongs to one of such groups. Judging from the figures of DUMBLETON (1966), it is inferred that the mesosome is absent in the male external genitalia of this species. I had an opportunity to examine the genitalia of this species based on the materials preserved in 70% ethanol and dried ones through the courtesy of Dr. G. H. GREHAN of Wellington University, New Zealand. In this paper I described and figured the external genitalia including male musculature, and discuss on the mesosome of the family Hepialidae.

Before going further, I would like to express my cordial thanks to Dr. Ryuzo TORIYAMA, Dr. Masamichi OTA and Prof. Emeritus and Dr. Takashi SHIRÔZU of Kitakyushu Museum of Natural History and Prof. Toyohi SAIGUSA of Kyushu University for their constant encouragement. I also express my sincere gratitude to Professor Toyohi SAIGUSA of Kyushu University for his kindness reading and criticizing this manuscript. I am much indebted to Dr. GREHAN of Wellington University, New Zealand, Dr. J. DUGDALE of DSIR, New Zealand, Dr. D. R. DAVIS, National Museum of Natural History, Smithsonian Institution, Dr. G. S. ROBINSON and Miss P. GILBERT of the British Museum of Natural History, Dr. N. TINDALE of California, U.S.A., Mr. PEÑA G., Santiago, Chile and Dr. Hiroshi INOUE of Otsuma Woman's University for their kindness giving me valuable informations and opportunities to examine the specimens.

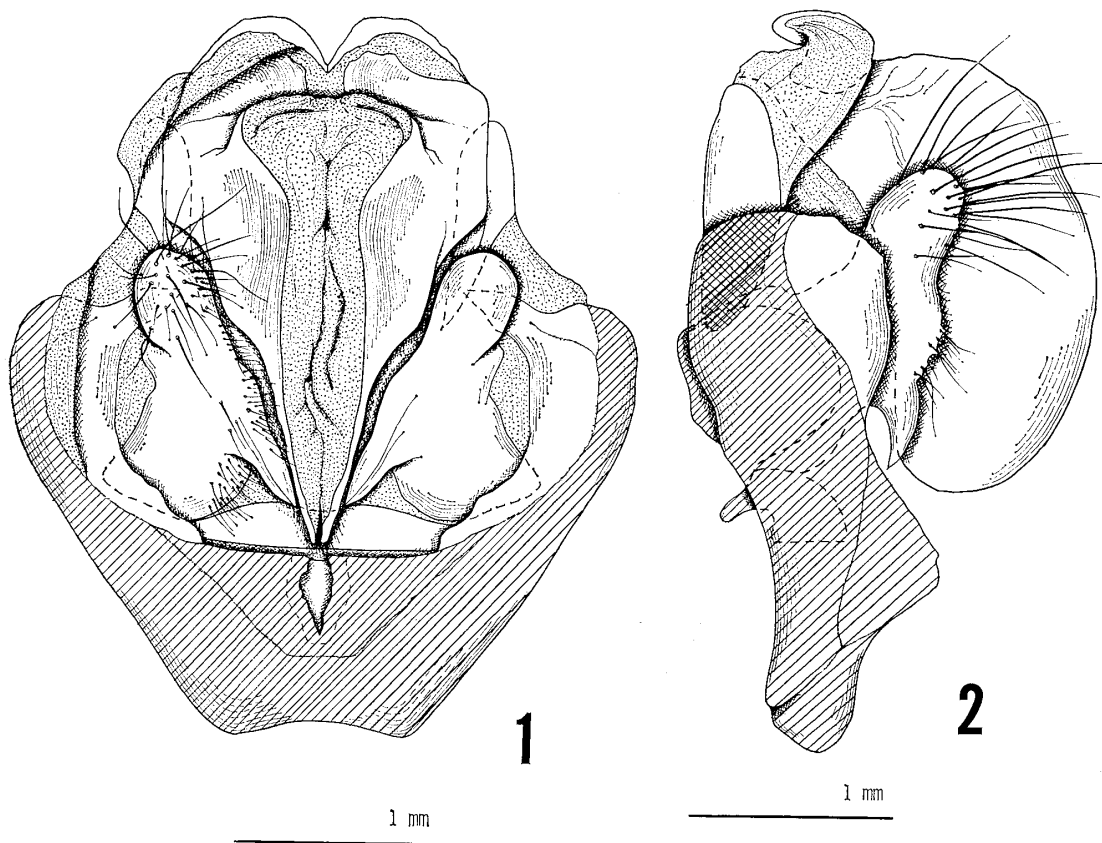
Description of Male and Female External Genitalia

Male (Figs. 1-4)

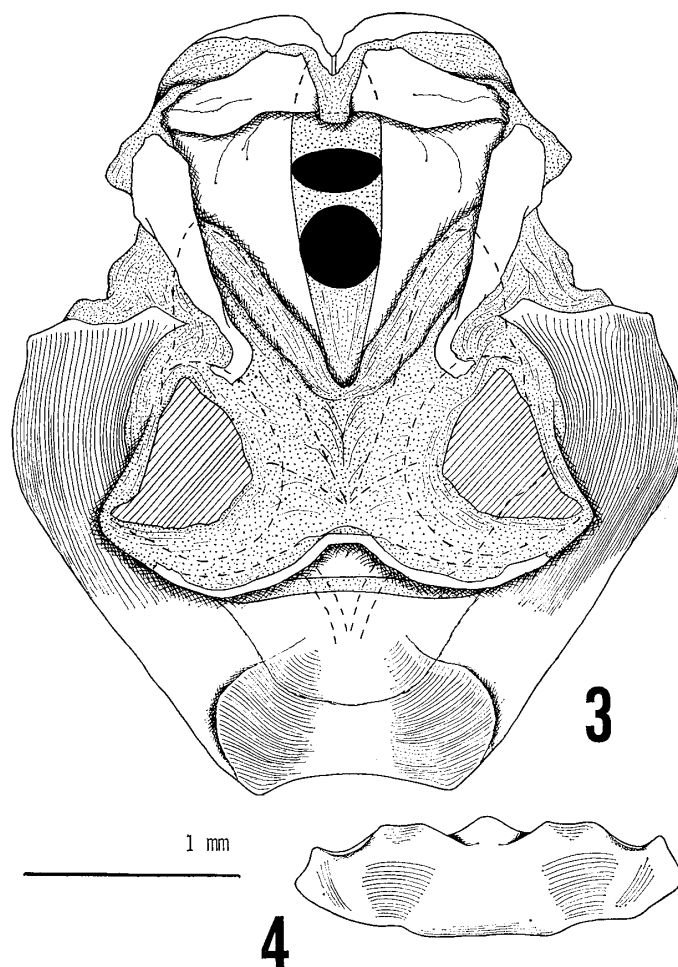
Tegumen very large and almost inverted triangular in shape in caudal view; twin process indistinct; processus momenti narrow, elliptical and definitely separated from tegumen by broad membranous region; valvella very broad, large and produced ventrally; the distal margin of valvella rounded; vinculum almost as deep as tegumen and U-shaped in caudal view, with a pair of triangular processes on the ventromedial portion of its posterior margin; saccus large, with a pair of swollen portions on dorsal wall, which are stretching outwards and function as the muscle attachment of m. 78. Valva large, two times as long as wide; the middle portion of its ventral margin projecting ventrally into a long process ended in an acute tip; the apical portion of valva rounded. Mesosome entirely absent. Tabulatum narrow, strongly sclerotized; the ventromedial portion and lateral margins of tabulatum swollen.

Female (Figs. 5-8)

On the terminal portion of abdomen a long and large plate is formed posterior to the sixth abdominal sternum. Two spiracles are present on the lateral membranous region between this plate and the seventh to eighth terga. These spiracles correspond with seventh and eighth abdominal spiracles, respectively (Fig. 5, arrows). Therefore, it is inferred that this plate is formed by the fusion of seventh and eighth ab-



Figs. 1, 2. Male genitalia. (1) Caudal aspect; (2) lateral aspect (left).



Figs. 3, 4. (3) Male genitalia; frontal aspect, (4) tabulatum; ventral aspect.

dominal sterna. In ventral view each lateral margin of this plate weakly expanded outward at basal 2/3 and its posterior margin concaved at the middle. The posterior margin of ninth tergum excavated triangularly at the middorsal portion and with minute hairs sparsely on this region. Ninth sternum strongly sclerotized and about four times as wide as high. A small membranous swelling present on each side of seminal gutter. Subanal plate narrow and weakly sclerotized.

Musculature of Male External Genitalia (Figs. 9–10)

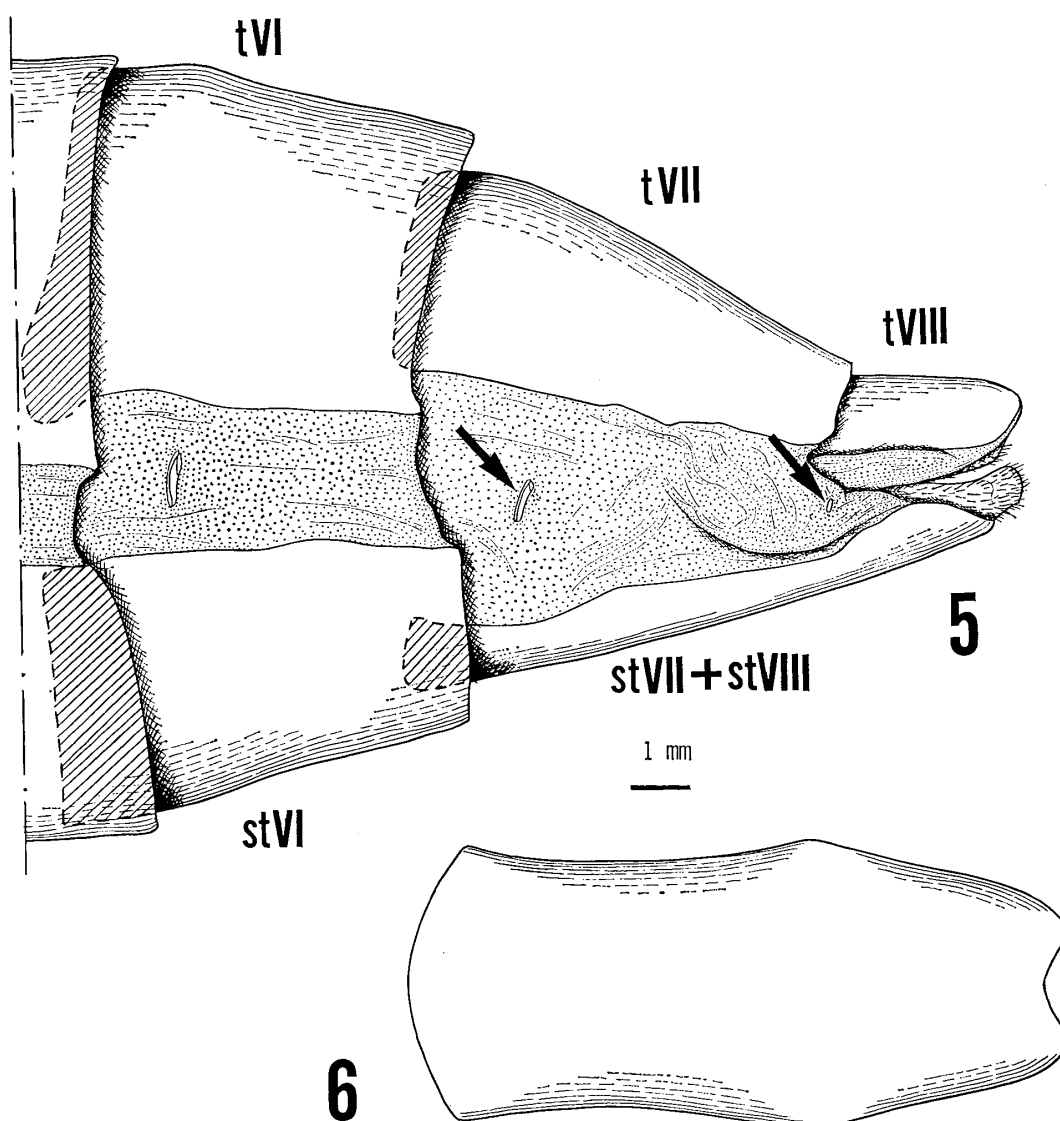
The nomenclature of musculature system is based on BIRKET-SMITH (1974).

m. 12 (tegumen-twin process): untraceable.

m. 3 (tegumen-processus momenti): absent.

m. 4 (vinculum-processus momenti): long and large muscle, arising from the middle of lateral portion of vinculum and inserted on the dorsal portion of processus momenti.

m. 5 (vinculum-processus momenti, vinculum-valva): broad and large muscle, well developed and divided by their inserted points in the following two bundles.



Figs. 5, 6. (5) Terminal segments of female abdomen; lateral aspect (left). Arrows indicate 7th and 8th abdominal spiracles respectively; (6) a plate posterior to the 6th abdominal sternum; ventral aspect (7th abdominal sternum + 8th abdominal sternum).

m. 5-1, moderately broad and short muscle, arising from the dorsal margin of vinculum and inserted on the ventral extremity of processus momenti; in some specimens, this muscle divided further into two bundles. m. 5-2, broad and large muscle, arising from the middle of lateral margin of vinculum and entirely inserted on the base of valva.

m. 6 (inner wall of base of valva-middle portion of ventral margin of valva): short muscle, taken its origin on the base of valva and attached on the inner middle region near its ventral margin.

m. 78 (vinculum-tabulatum): very large and stout muscle, divided into two bundles, arising from the ventral portion of vinculum and inserted on the tabulatum.

m. i9 (tegumen-tegumen, tegumen-ductus ejaculatorius, processus momenti-

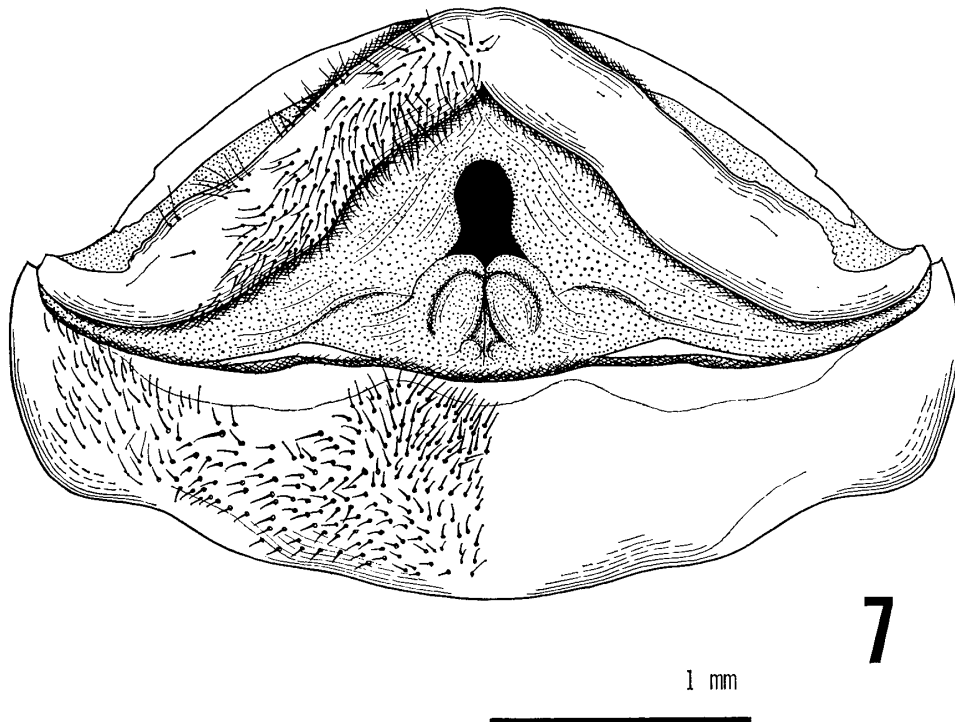


Fig. 7. Female genitalia; caudal aspect.

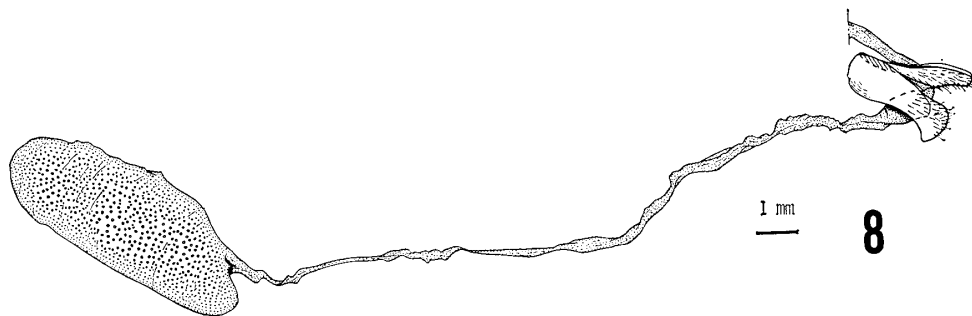


Fig. 8. Female genitalia; lateral aspect (left).

ductus ejaculatorius): very large muscle and divided into the following three parts by their inserted points. mi9-1, the large transverse muscle interconnects the subdorsal walls of tegumen. mi9-2, short muscle, arising from the subdorsal region of tegumen and inserted on the dorsal portion of ductus ejaculatorius. mi9-3, extensively large muscle, arising from the inner wall of processus momenti and inserted on the lateral wall of ductus ejaculatorius, and ventral portion of this muscle passing below ductus ejaculatorius and interconnects the two processi momenti.

m. 10 (processus momenti-valvella): large and long muscle, arising from the middle of the posterior margin of processus momenti and inserted on the middle portion of valvella.

m. 11 (dorsal wall of subgenital crypt-valvella): untraceable.

Discussion

In comparison with the structure observed in some species of *Hepialus* and *Endo-*

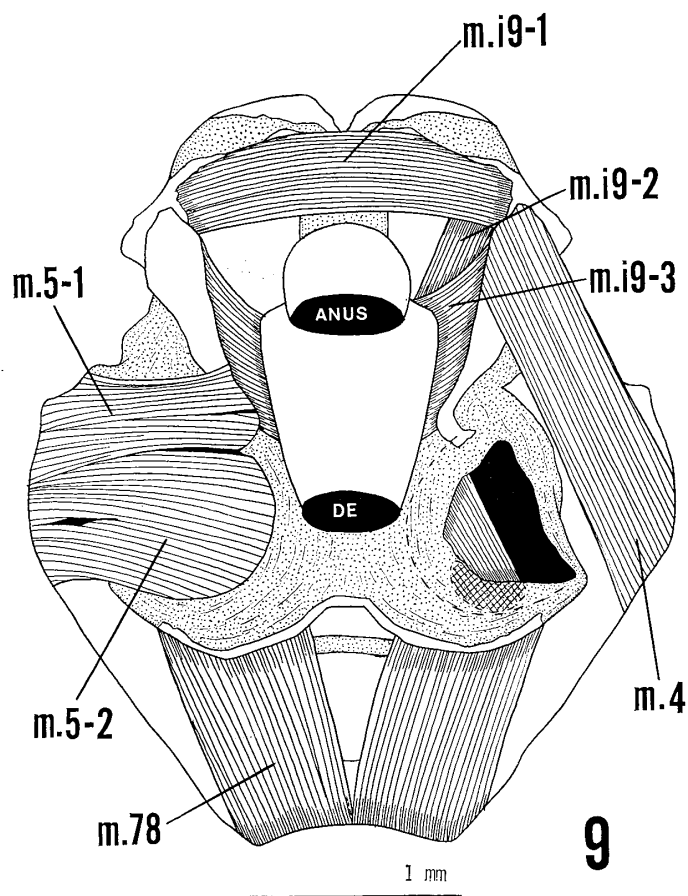


Fig. 9. Male genitalia showing its musculature; frontal aspect.

clita, we can easily find the following characteristics in the male external genitalia of *Aenetus virescens*: 1) the absence of mesosome, 2) enlargement of valvella, 3) the presence of an acutely pointed long process from the ventral margin of valva and 4) extensive development and enlargement of m.5. In contrast with these specializations in male, the structure of female external genitalia is basically the same as that of *Hepialus* except for the formation of large plate on the ventral extremity of abdomen. This plate is inferred to be brought about by the fusion of seventh and eighth sterna as mentioned above.

The firms coupling between male and female external genitalia during copulation, which were observed in *Endoclita excrescens* (BUTLER) and *Hepialus fusconebulosa* (De GEER), is mainly attained through the following movements: 1) opening and holding of the seminal gutter on the female diaphragma by laterally opening male valvellae, 2) grasping of the female diaphragma by the male valvae, which act against the valvellae from outside, and 3) grappling of the female central groove or the sclerotized portion on the ventral region of ostium bursae by the male mesosome (UEDA, 1981). Except for a fusion of the seventh and eighth abdominal sterna the female genital structure of *Aenetus virescens* is not so differentiated from that of *Hepialus*. Taking this fact into consideration, even in this species, it is inferred that the mode of coupling between male and female external genitalia is basically the same as the mode mentioned above. Therefore, the function to grapple female external

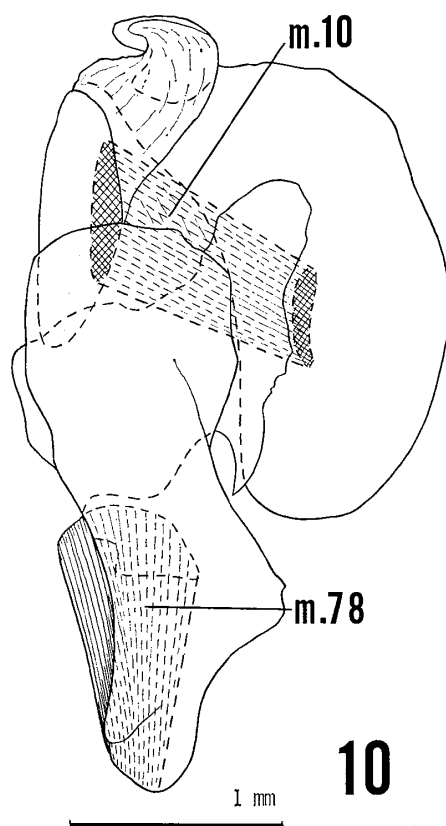


Fig. 10. Male genitalia showing its musculature; lateral aspect (left).

genitalia by the mesosome should be substituted by other structure in *A. virescens*. Judging from position and form of valva, the development of m. 5 and the insertion of m.6, it is most probable that the acute process from the ventral margin of valva is this substituted structure.

Although the observed materials are rather few in number, the character-states of mesosome are classified into the following four types (Fig. 11, A-D).

Type A: the mesome is formed by the ventromedial union of a pair of prolongations, which are produced from the ventral margins of lateral portions of tegumen. This type of mesosome is observed in the genera *Endoclita*, *Hepialus*, *Zenophasus* and *Oncopera*, and also in the family Paleosetidae (*Ogygioses caliginosa* ISSIKI & STRINGER).

Type B: a large and well sclerotized hollow process is developed as mesosome below the ventral margin of tegumen. This type of mesosome is observed in *Hepialus hecta* L. and *H. tacomaea* EDWARD.

Type C: mesosome is not formed. Valvellae are not fused with each other on the ventromedial portion of tegumen. This type is observed in the genera *Aenetus* and *Oncopera*.

Type D: mesosome is not formed. The ventral portions of valvellae are completely fused with each other and, as the result, whole tegumen forms the semi-circular ring. In some species small sclerotized plates are present on the inner wall of ductus ejaculatorius near its opening and these plates are similar to cornuti in ditrysian Lepi-

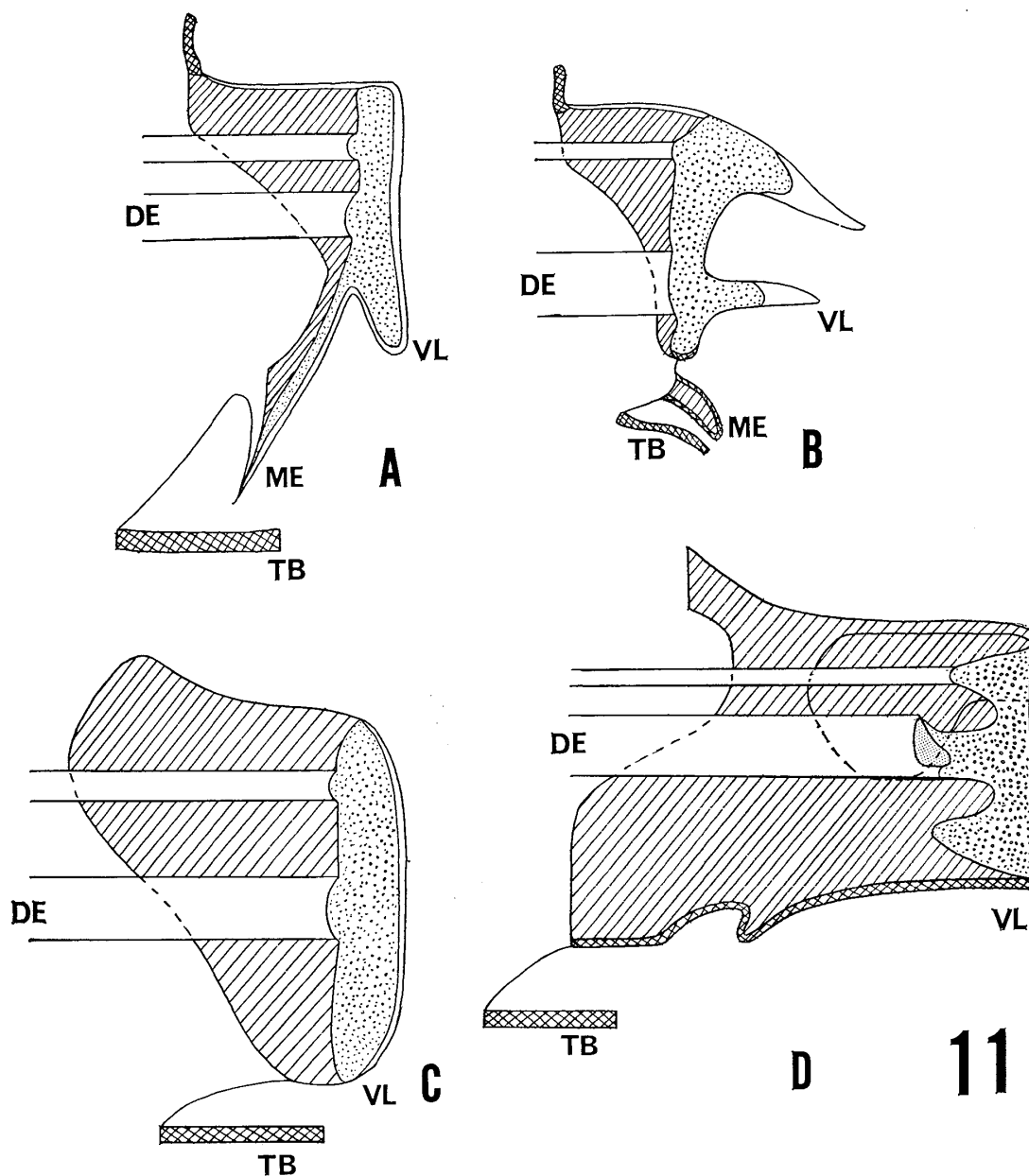
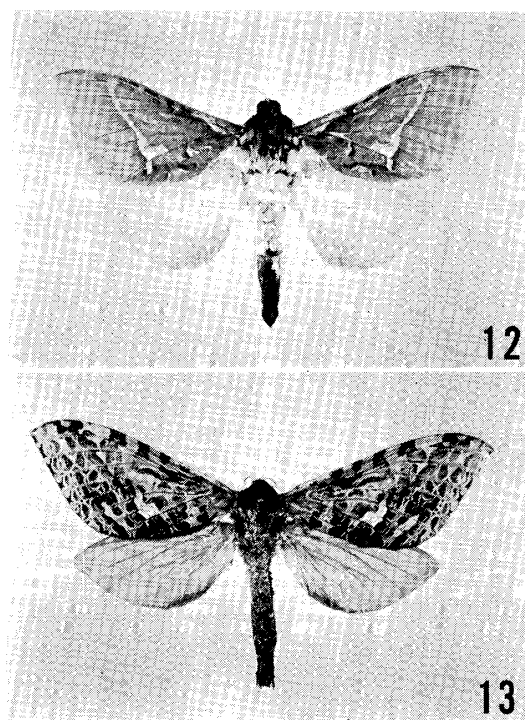


Fig. 11. Diagrams showing various character-states of mesosome in Hepialidae (sagittal section). A: Type A; mesosome is formed by the ventromedial union of a pair of prolongations from ventral margin of tegumen. B: Type B; mesosome is developed as a large and well sclerotized hollow process. C: Type C; mesosome is not formed and valvellae are not fused with each other. D: Type D; mesosome is not formed and valvellae are fused with each other. DE; ductus ejaculatorius, ME; mesosome, TB; tabulatum, VL; valvella (see text).

doptera. Type D is observed in the genus *Callipielus*.¹⁾ When the sclerotization on dorsal region of tegumen is progressed from this condition in type D, the whole tegumen becomes a complete ring in caudal view. This condition is observed in some species of South American Hepialidae.

¹⁾ ROBINSON (1977) used a term "juxta" for his trulleum and this semicircular structure on the ventral portion of tegumen (his "its caudal sclerotized extension") (*l.c.* p. 106 and Fig. 1). Judging from



Figs. 12, 13. *Aenetus virescens* (DOUBLEDAY). (12) Male; (13) female.

The genus *Oncopera* is heterogeneous in this respect, and the type A and C are observed in it (COMMON, 1966). In the species of type C, which has no mesosome, either the valva is enlarged (*i.c.* Figs. 1–5) or the process from the ventral margin of valva is developed (*i.c.* Figs. 6, 10–12). On the contrary, in the species of type A, which has well developed mesosome, the valva is narrowed, small in size and without any process from its ventral margin. This variation of structure in male genitalia is very interesting in suggesting antagonistic relationship between the grappling function of mesosome and that of valvae.

As mentioned above, the extensive transformation of mesosome is found even in the family Hepialidae, and it is inferred that this structure is one of the important characters for the analysis of phylogentic relationship in this family. But more extensive comparative analysis will be needed over related groups to clarify the homology of mesosome.

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the work of PHILPOTT (1927), trulleum is the sclerotized portion of the ventral wall of mesosome in its original use (UEDA, 1978, Table 1). The problem, whether the juxta in ditrysian Lepidoptera is a homologous structure with the tabulatum in Hepialidae or not, is still remained unsolved. However, homology between juxta and tabulatum is almost certain considering from the position of tabulatum and its musculature. Moreover, in *Callipielus arenosa* BUTLER, which I observed in the course of this study, tabulatum is present anteroventral to this semicircular structure and they are separated by broad membranous region from each other. Therefore, it is preferable to me that the term juxta is not used for this semicircular structure.

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摘 要

Aenetus virescens (DOUBLEDAY) の雌雄外部生殖器と雄外部生殖器の筋肉系
(上田恭一郎)

ニュージーランドに産する大型の緑色のコウモリガ *Aenetus virescens* (DOUBLEDAY) の雌雄外部生殖器の構造および雄外部生殖器の構造および雄外部生殖器の筋肉系を図示し記載した。本種の雄外部生殖器の構造では次の形質状態が特徴的である。すなわち 1) mesosome が欠如する, 2) valva 下縁の中央部より先端が鋭くとがった突起が腹方へ伸びている。雄外部生殖器の筋肉系では *Hepialus* 属および *Endoclita* 属と基本的な差はみられないが, vinculum と valva を結合する m. 5 が非常に発達し, 大型化している。雌外部生殖器の構造は第 6 腹板の後方に大型のプレートが形成されることを除けば, *Hepialus* 属の雌外部生殖器と基本的な差はみられない。このプレートと第 7, 第 8 背板の間の膜質部に第 7, 第 8 気門が存在することから, この大型のプレートは第 7, 第 8 腹板が融合して形成されたものと推測される。

本種の交尾の際の接合様式は不明であるが, 上述したように雌外部生殖器の構造が *Hepialus* 属と基本的に同一であること, 雄外部生殖器において mesosome が欠如し, valva の下縁から腹方へ鋭い突起が突出すること, また valva へ付着する筋肉 m. 5 が非常に発達することから推測すると, *Hepialus* 属や *Endoclita* 属で“腹方の uncus”として働いていた mesosome による雌外部生殖器の把握機能は, valva 下縁の突起によって代行されているように思える。

これまで観察されたコウモリガ科の雄外部生殖器の構造は mesosome の発達状態をもとにすると次の 4 つのタイプに分けられる (Fig. 11), すなわち

A型: tegumen の側域の腹縁から下方へ伸びた突起が腹中線部で融合して mesosome を形成する。このタイプは *Endoclita* 属, *Hepialus* 属, *Zenophasus* 属, *Oncopera* 属および *Palaeosetidae* の *Ogygioses caliginosa* ISSIKI & STRINGER で観察される。

B型: 大型の中空になった突起が mesosome として tegumen 下縁の腹中線部に発達するもので, キンシコウモリ *Hepialus hecta* L. と *H. tacomaea* EDWARD で観察される。

C型: mesosome は発達せず valvella が腹中線部で融合しない。このタイプは *Aenetus* 属, *Oncopera* 属で観察される。

D型: mesosome は発達せず valvella が腹中線部で完全に融合し, tegumen は半環状の形態を呈する。このタイプは南米の *Callipielus* 属で観察される。このタイプには tegumen 背域がさらに骨化し, 後方からみると tegumen 全体が完全な環状構造を呈する種もある。